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**NAVAL SUBMARINE MEDICAL
RESEARCH LABORATORY**

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REPORT NUMBER 770

LENTICULAR OPACITIES AND THE EVALUATION OF PERSONNEL
FOR THE NAVAL NUCLEAR PROPULSION PROGRAM

by

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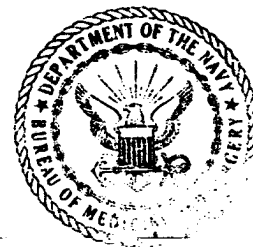
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FOREWORD

Undersea

Occasionally, the ^{NSMRL} ~~Laboratory~~ sees fit to publish reports that do not constitute pure research, nor *do these* report on any specific Research Work Unit. Reports of this type usually are selections from theses submitted by submarine medical officer qualification candidates. These theses, as a rule, constitute discussions of medical problems in the operational submarine or diving field, unusual medical problems in which unique improvisation of equipment or methodology provided a solution, well thought-out discussions, or literature reviews on occupational problems applicable to the submarine and diving medical fields.

This type of report is published for dissemination to Submarine Medical Officers and their Medical Department aides and to those interested in submarine *undersea* medical research and development.

Lieutenant Philip R. Albert's report falls in one of the ~~above~~ categories described above, and has been selected for publication as an NSMRL report.

Charles F. Gell, M. D., D.Sc. (Med)
SCIENTIFIC DIRECTOR

THE PROBLEM

To review matters pertinent to the evaluation of lenticular opacities in personnel in the nuclear power program.

FINDINGS

By virtue of its structure, physiology, and location, the lens of the eye is susceptible to cataract formation by doses of radiation higher than those received in the nuclear power program. Radiation health considerations require that certain types of cataracts be considered disqualifying from the nuclear field. Ophthalmoscopy, supported by a thorough general ocular history, physical examination, and refraction, is a satisfactory initial screening, with slit lamp examination required under some circumstances. Medicolegal considerations underscore the need for a vigilant radiation health program and a clear understanding of the biomedical implications of radiation exposure, especially since unwarranted adverse decisions have already been made.

APPLICATION

This paper provides information to individuals involved in radiation health and nuclear power, and it makes recommendations concerning the evaluation and disposition of lenticular opacity problems.

ADMINISTRATIVE INFORMATION

This report was prepared in partial fulfillment of the requirements for qualification in Undersea Medicine. It has been selected for publication in order to make the information available in the Technical Library, and for use of the students in the Naval Undersea Medical Institute, NavSubBase, Groton, CT. *at NavSub Med Res Lab*

The manuscript was approved for publication on ^{1 AUGUST} June 1974, and designated as NavSubMedReschLab Report Number 790.

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THE NAVAL NUCLEAR PROPULATION PROGRAM

by

Philip R. Albert
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NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

REPORT NUMBER 790

Bureau of Medicine and Surgery, Navy Dept
Research Work Unit MF099.01.01.12

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ABSTRACT

Pertinent aspects of lens anatomy, embryology, and physiology are reviewed. Types of cataracts are described and classified as to etiology. The pathophysiology of radiation cataracts is discussed and data regarding dose levels needed to produce such cataracts is presented. The requirements for satisfactory screening for lenticular opacities and for their further evaluation is discussed in light of results achieved at the Nuclear Power Schools. Medicolegal ramifications are discussed and compensation cases reviewed. ^{Suggestions} ~~Recommendations~~ are made concerning acceptable examining protocols, administrative processing, disqualification criteria, and approaches to minimizing adverse, unwarranted legal decisions.

TITLE in ALL CAPS

INTRODUCTION

Paralleling the development of nuclear power as a source of energy during the past 30 years has been a concurrent awareness of the harmful effects of radiation on biological systems. Most of the data has come from accidents occurring at nuclear power plants in early years, side effects observed in patients as a result of therapeutic irradiation procedures, and delayed changes occurring in survivors of nuclear weapons detonations. This latter group has been the subject of especially intense longitudinal follow-up and analysis. All three of these groups share the association of exposure to large doses of radiation, while occupational workers in nuclear power plants are limited to doses small enough to preclude such injury. It is incumbent upon cognizant authorities in nuclear power systems, however, to consider the hazards of radiation when determining the qualification of workers for the nuclear field.

The matter of lenticular opacities has long been a troublesome issue for the Naval Nuclear Propulsion Program for two reasons. First, cataracts have arisen as a result of exposure to radiation, albeit large doses. Second, these cataracts may resemble opacities that occur either spontaneously or as a result of other pathology. Both medical department and line personnel continue to encounter the confusion this issue breeds; indeed, the absence of firm procedural guidelines prevents the resolution of specific cases at local command levels.

This paper endeavors to review those aspects of lenticular opacities

that are pertinent to the Naval Nuclear Propulsion Program. It contemplates an audience of medical department members who must evaluate candidates, line personnel who oversee the programs, and occupational workers who perform radiation work. It is hoped that the issues at hand will be clarified and that the recommendations here contained will improve the evaluation and disposition of lenticular opacity problems.

LENS DEVELOPMENT AND STRUCTURE

The lens arises from surface ectoderm that overlies the optic vesicle and thickens into a lens placode. As lens fibers are laid down, their ends meet to form the suture lines appearing in the nucleus. The fetal lens initially receives its blood supply from the hyaloid artery, which arises near the optic nerve and extends through the vitreous body. At about the fifth month the hyaloid system atrophies and disappears; vestigial remnants often persist and are termed Mittendorf dots.¹

The mature lens is a biconvex disc with a horizontal dimension of approximately 10 mm and a thickness of about 4 mm. The anterior and posterior surfaces join at the equator. Surrounding the lens is an elastic, acellular capsule. Underlying the anterior capsule is a single row of cuboidal epithelium. Lens substance, laid down by the epithelium, consists of fibers embedded in intercellular cement. New lens fibers are elaborated by cells at the equator and extend their processes anteriorly and posteriorly. —Older fibers are pushed, with their cell

bodies, toward the center of the lens, thus creating an equatorial nuclear bow. Aging of the lens results in shrinkage, compression, and loss of fiber elasticity; thus the nucleus, which can be distinguished from the cortex, increases in size over time.²

Overlying the adult lens are the cornea, 0.6-0.8 mm thick, and the anterior chamber, 3.0-3.6 mm thick.³ Hence direct radiation damage to the lens must penetrate through 4.0 mm of tissue density to reach the lens. It is in part this proximity to the surface that makes the lens a critical organ with a large relative biological effect for high-LET radiation.⁴

The lens owes its transparency to its relative acellularity and a uniform refractive index of its various parts. Its composition is primarily crystalline protein, consisting of alpha (embryonic) and beta (adult) forms. A high intralenticular potassium content is maintained by the anterior epithelium. Other biochemical distinctions include a high content of both glutathione and Vitamin C. Glucose metabolism occurs chiefly via the Embden-Meyerhof pathway leading to lactic acid, since the amount of oxygen available for oxidative phosphorylation is restricted by what can diffuse through the aqueous humor.⁵

LENTICULAR OPACITIES

Any interruption of the normal transparency of the lens is termed an opacity or cataract. By many, however, including those involved in

the naval radiation health program, the word "cataract" is generally reserved for those opacities with a pathologic, as opposed to a physiologic, etiology. The mechanism whereby cataracts occur involves either denaturation of the protein or hydration of lens substance. It has been suggested, further, that the high levels of glutathione present in the lens exert a protective influence against the development of cataracts.⁶

Of the several recognized methods of classifying opacities, the one involving etiology is the most relevant for the purpose of evaluating personnel for occupational exposure to radiation. In these terms, they may thus be regarded as congenital, hereditary, metabolic, toxic, associated with other ocular disease, traumatic, and degenerative.

Congenital cataracts are usually punctate, irregular opacities that are found with a slit lamp as minor aberrations in an otherwise normal lens.⁷ Otherwise, they may be present as Mittendorf dots. Iris pigment, although found on the lens surface by examiners, does not constitute a true lenticular opacity. Those congenital cataracts that occur in connection with prenatal disease, such as rubella or toxoplasmosis, are accompanied by major defects in other organ systems and hence are not likely to present among candidates for the nuclear propulsion programs. Nonetheless, case evaluations have been submitted to the Bureau of Medicine and Surgery in which dense cortical and subcapsular opacities, distinctly more prominent than small flaws, have been described as congenital in their origin, without any associated

findings.⁸ For hereditary cataracts a family history of similar lesions must be present.

Metabolic cataracts occur in association with adult-onset diabetes, hypocalcemia, and pituitary disease. Diabetic cataracts occur in subcapsular cortical regions, both anterior and posterior, and resemble a "snowflake" pattern. Hypocalcemic cataracts may have a similar appearance, although they do not arise unless the serum calcium is low enough to make tetany likely. Opacities occurring in conjunction with ~~pituitary~~^{pituitary} disorders are extremely rare.⁹

Traumatic cataracts can also originate in the posterior subcapsular region, regardless of the site of original injury or whether the injury involved a blunt contusion or a penetrating wound. At the time of detection, however, they can present a varied appearance, and case reports submitted to the Bureau of Medicine and Surgery for evaluation have been both anterior and posterior. Virtually all have been in cortical regions.¹⁰ Toxic cataracts occur in the same portion of the lens and "resemble mainly senile peripheral cortical or posterior subcapsular opacities."¹¹ Corticosteroids, both topical and systemic, represent the most important group of medications that have been implicated. In addition, chlorpromazine has been found to cause pigment deposition in the anterior lens.¹²

Senile or degenerative cataracts occur most commonly in the cortical regions and are usually posterior subcapsular, where they give rise to a "beaten-gold" appearance. Unlike the degenerative nuclear hard

cataract, which results from the sclerosing process of aging, the soft cortical cataract involves protein denaturation and hydration. It is fluid accumulation that creates a typical spoking pattern.¹³

In a relatively young and healthy cohort like the Navy, it is rare for an opacity to manifest as a noticeable decrement in visual acuity. When specifically sought, however, some form of opacity can be found in a majority of individuals. Slit lamp examinations performed in a study of both nuclear and diesel submariners at the Naval Submarine Base, Groton, Connecticut, showed punctate opacities, regarded as physiologic, in over 95%.¹⁴ In a more recent slit lamp study of 33 civilian workers at a naval shipyard, 75% were found to possess opacifications.¹⁵ When only the ophthalmoscope was used by Navy physicians specifically seeking opacities, a 5% yield has been reported.¹⁶

The most extensive program of concentrated mass screening for lenticular opacities under naval auspices lies in the collective experience at the Nuclear Power Schools located at Bainbridge, Maryland, and Mare Island, California. All candidates for the nuclear propulsion program, officer and enlisted alike, receive a thorough preplacement radiation physical examination at the commencement of each class. Every candidate is carefully screened by an optometrist with an ophthalmoscope. All opacities thus detected are further evaluated by the optometrist with a slit lamp examination. Every lesion that is accompanied by other ocular disease, implicated in diminished visual acuity, or questionable in any way is referred for ophthalmology evaluation at a naval hospital.

The final evaluation for retention in the nuclear power program is made by the Bureau of Medicine and Surgery.

An assessment of the results of these examinations is important for several reasons. First, the large number of candidates examined and the technical quality of the screening process provides an index of the results that can be expected under essentially optimal conditions using this technique. It is of note that the screening protocol as currently followed is acceptable to cognizant authorities in the Bureau of Medicine and Surgery, NAVSHIPS 08 (Naval Reactors), the Bureau of Naval Personnel, and Type Commander staffs. Further, a survey of these results shows how many individuals have been lost to the nuclear propulsion program by reason of lenticular opacities and provides a means for estimating future attrition. Finally, in the event that either the location or the procedure for these examinations is changed in the future, a measure of quality control by comparison with past experience will be possible.

Data was collected from reports on enlisted personnel submitted by the Nuclear Power Schools to the Bureau of Medicine and Surgery after each class had ^{been} ~~its~~ physical ^{ex} ~~examinations~~ ^{ad.} performed. By convention, all candidates are placed in five categories according to physical defects that would disqualify them from submarine service, the nuclear power program, or both. A special Category IV lists all individuals with lenticular opacities. Men with more than one defect are placed in all categories that apply.

Table I summarizes the reports submitted from May, 1973 to May, 1974

concerning enlisted candidates. The overwhelming majority of these ~~men range in age~~ people are, from 18 to 21 years, ~~of age~~. The total number of 4,039

is confirmed by a BUPERS estimate of the number of candidates that reported to the Nuclear Power Schools in this time period. The overall 11.44% incidence of lenticular opacities identified with the ophthalmoscope is closely approximated ⁱⁿ by results ^{obtained} at both Bainbridge and Mare Island.

Tables II and III, ^{present} ~~further compile~~ the data by year and school. It can thus be seen that the range, considering large groups of people and multiple examining sessions, is 7.66% to 15.19%. It is ~~felt~~ ^{presumed} that this range reflects primarily a true variance in incidence.

~~Insert Tables about here~~
About 6 of the candidates during the time period examined were found to have lesions disqualifying them from the nuclear power program (final decision on ^{one} is currently pending). This constitutes 1.30% of those with lenticular opacities and 0.15% of all candidates on whom physical examinations were performed. It is therefore apparent that the attrition rate due to opacities at the onset of the nuclear power program is not a significant problem.

It is of historical interest that, when the importance and significance of lenticular opacities was not generally appreciated by medical department personnel, it was ^{the procedure} ~~decided~~ to find them all disqualifying, so that BUMED review (and waiver recommendation) would be required.¹⁷ Subsequently it was decided simply to forward all cases of opacities to

BUMED for final decision, thus removing the ^{possibility} ~~onus~~ of disqualification ^{for} ~~from~~ benign conditions. In the future, it is hoped ^{that} ~~to exempt~~ certain types of opacities ^{can be exempt} from BUMED review.

RADIATION CATARACTS

Radiation cataracts are thought to arise as a result of damage to the anterior subcapsular epithelium. Lenses examined in cataract patients have shown that cytologic changes occurring before lens opacification produce alterations in cell differentiation. [↑] The damaged cells and their fibers are pushed. In the normal process of lens maturation, toward the posterior pole. Cellular degeneration is accompanied by the release of enzymes that result in liquefaction of adjacent areas of the cortex.¹⁸

An extensive histological study was performed on the cataractous lens of a Hiroshima survivor who had been 780 meters from the hypocenter of the blast.¹⁹ By other workers it would be estimated that he sustained doses of about 200 rads of gamma and 160 rads of neutron radiation.²⁰ Fourteen days later this individual noted epilation of the scalp which progressed to baldness over the next 3-4 days. Two years later he was examined for failing vision and ^{found} noted to have bilateral opacities. Four years after the blast, in 1949, his left lens was removed. Histologically it was located in the posterior subcapsular region, where it appeared as a lace-like disc with small vacuoles. The borders were sharply defined and thickened, giving rise to a doughnut appearance.²¹ This is

a prototype description of a radiation-induced cataract, although with further opacification it may resemble other types of posterior subcapsular cataracts.

Survivors of the atomic bomb explosions at Hiroshima and Nagasaki have formed the largest group of individuals available for long-term follow-up of delayed effects, including lenticular opacities. By fixing the precise location of these individuals at the time of the detonations, it has been possible to estimate the doses of radiation they received. One study has been conducted by the Atomic Bomb Casualty Commission, a binational group that has examined survivors every two years since 1958. By 1968 they found an increased prevalence of diseases of the eye, most of which were cataracts, for individuals who had received more than 100 rads. For the groups that received ~~0-9 rads and 10-99 rads~~ *less than 100 rads*, however, ~~no~~ *no* increased prevalence was not found.²²

In another study of survivors In 1949, Fillmore found 98 cases of cataract among Hiroshima survivors, 85 ~~of whom~~ *of whom* were within 1000 meters of the hypocenter. (According to Belsky, people 1000-1049 meters from the hypocenter received a mean air dose of 219 rads gamma and 160 rads neutron.²³) Subsequent examinations of 3700 survivors, ~~from 1951-53~~ *conducted*, revealed 154 individuals with posterior subcapsular, polychromatic cataracts visible with the ophthalmoscope. These cataracts were associated with epilation and other effects, ~~and in only 25 was vision correctable to less than 20/25~~ *radiation. Vision was correctable to 20/25 and better in all but 25 of these survivors.* By 1956, a National Academy of Sciences and National Research Council report stated that, among the 8000 survivors of both explosions,

10 cases of severe cataract had been discovered, 25 cases involving slight impairment of vision, and 200 additional instances of minimal lesions detected by the slit lamp alone.²⁴

About the time that radiation cataracts were being discovered in survivors of the atomic bombs, cases were coming to light involving physicists working with cyclotrons, which produced high fluxes of fast neutrons and hard gamma rays. By 1949, ten cyclotron scientists had been diagnosed as having radiation cataracts. Exposure times varied from 10 to 250 weeks, and dose estimates, acknowledged to be poor, ranged from 8 to 270 rem of neutrons. Further, among ten scientists involved in the nuclear accidents at Los Alamos Scientific Laboratory, *during the period* August 1945 and May 1946, two developed cataracts. One had been within 3 feet and was estimated ~~to~~^{to} have received a neutron dose of 45 rem and a whole body gamma dose of 26 ~~x~~^{rem}. Two others, 6 and 8 feet away and receiving an estimated 21 and 15 rem of neutrons to the eye and 11 and 9 ~~x~~^{rem} whole body gamma, respectively, did not develop cataracts.^{25,26}

While cataracts have been thus observed among atomic bomb victims, scientists, and patients receiving therapeutic radiation to the head as well, there is not sufficient evidence to prove a human "threshold" below which cataracts will not develop. Patients have required doses in the range of 600 ~~x~~^{rem} of gamma to develop cataracts.²⁷ Animal experiments have provided some interesting although inconclusive data. In

mice, for example, which are known to be very susceptible to radiation opacities, a significant increase in opacification has resulted from ^{one} rad of neutrons.²⁸ While it is not possible to extrapolate the numerical data to man, such data has been taken to suggest that a threshold dose of neutrons for lens opacification may not exist.²⁹

It is presently considered that, on the basis of available data, there may be "a practical threshold for the induction of vision impairing lens opacification in man by low-LET radiation...."³⁰ For x-rays and gamma rays, "the dose-response relation for the induction of cataracts severe enough to impair vision seems ^{to indicate a graphically} clearly to be sigmoid^{shape}...."³¹ The practical threshold for these types of radiation has been estimated to lie in the range of 200 - 500 rads for single exposures and about 1000 rads for fractionated exposures delivered over months. For neutron exposures estimates of 20 - 45 rads³² and 75 - 100 rads³³ have been made.

The significance of the scientific and clinical data thus far accumulated on radiation cataractogenesis, then, can be as stated in the widely recognized BEIR report: "These considerations imply that there is little risk of inducing such effects at doses and dose rates approaching natural background radiation levels."³⁴

MEDICOLEGAL PROBLEMS

As the radiation health program must safeguard the well being of radiation workers, so must it be concerned with the compensation system

as currently applied in the event of radiation injury. In particular a radiation health program must be alert to specious claims, born of ignorance, ill advice, superstition, or other motives best known to the plaintiffs, since protection of the Government (taxpayer) is as worthy a goal as protection of the worker. To date no compensation claims have come from ~~naval~~ personnel. A number of claims have been submitted by civilian personnel, however, some of them ^{were} working in shipyards on ~~naval~~ projects.

The U. S. Atomic Energy Commission has compiled a series of volumes in which cases involving alleged radiation injury are presented. Volumes V and VI, published in 1969 and 1972, contain several cases, both private and governmental, involving cataracts. Their summary provides an excellent overview of the development of compensation standards. ^{from the following} the 1969 compendium: ³⁵

Case 5. Compensation denied a claimant who received 332 mrem over a six year period while erecting staging on a structure housing nuclear reactors. His cataracts did not resemble radiation cataracts and had existed at least ^{seven} years prior to his earliest exposure.

Case 12. Compensation denied a claimant who received an estimated ^{rem four} 200 X over ^{four} years while inspecting electronic and communications equipment. While his cataract resembled one that could arise from radiation, it was determined that he had not received a cataractogenic dose.

Case 21. Compensation denied a physicist who in ^{eight} 8 years received

Instances are cited

more
 2033 ~~mr~~ (955 ~~mr~~ gamma and 108 ~~mr~~ neutron), including 1063 ~~mr~~ *more* in one year. It was determined that, while he had posterior subcapsular opacities, they were not radiation-induced, inasmuch as the dose was too small and he had associated macular and vitreous changes that would not result from radiation.

Case 24. Compensation granted a geophysical research scientist who had initially sustained a microwave exposure from 1942-1945. Subsequently, from 1948-1950 he operated an electron microscope, whose use was terminated when it was found to emit x-rays of unknown intensity. He developed premature cataracts, the lesion in the right lens being pathognomonic for microwave cataracts. It was determined that his cataracts were caused by microwaves and aggravated by x-rays.

Case 42. Compensation denied an electrical foreman who worked near but not in a gamma radiation area and whose film badge showed zero exposure.

Four more cases are summarized below,
 from the 1972 compendium:³⁶

Case 5. Compensation denied a worker with the Manhattan Engineer District who never handled radioactive materials but who, along with others, looked through an observation window at an ion beam and ion source. He ascribed the subsequent development of adenocarcinoma of the colon, cataracts, glaucoma, and a detached retina to radiation, but his claim was refused.

Case 36. Compensation denied a worker who received 35 ~~mr~~ *more* from a

cesium source over $8\frac{1}{2}$ months. While he could conceivably have gotten into the path of several hundred rem per hour, it was demonstrated by safety precautions and the absence of skin and hair changes that such exposure ^{probably} had not occurred.

Case 44. Compensation granted a female chemist at a ~~naval~~ shipyard who handled radioactive materials, primarily reactor plant water. Film badge records showed a total dose of 1.690 rem by 1965, when she was noted to have bilateral, discrete, thin, beaten-gold, vacuolized posterior subcapsular cataracts. An ophthalmologist who felt this was an early senile change said in part that these cataracts "could be an unusual sensitivity of the germinal epithelium to a low volume radiation..." By 1970, when the cumulative dose was 3 rem, the Medical Director said in part, "I must conclude, therefore, that the slight progression of these cataracts, subcapsular in type, were initiated or certainly aggravated by the radiation exposure." The decision in the claimant's favor was made by the Board of Employee Compensation.

This case, which arose in connection with the naval ~~Nuclear~~ power program, has generated vigorous and sustained rebuttal efforts by ~~Naval~~ personnel having cognizance over nuclear reactors and the radiation health program. Despite a subsequent array of expert opinion disputing the claim and a recent appeal by ~~Naval~~ authorities, however, the ^{Board of Employee Compensation} ~~BEC~~ has recently reaffirmed its original decision.

Case 50. Compensation granted a California physicist who received a twelve year exposure of 0.61 ^{rem} R while working around accelerators. An

ophthalmologist with prior experience involving radiation cataracts said the lesions were "quite typical of the cyclotron cataracts, and the type I saw in Hiroshima." He continued that "The posterior subcapsular cataract in the right eye has the bivalve appearance which is so characteristic of radiation cataracts. Therefore, ^{there} ~~it~~ doesn't seem to be much doubt that he has radiation cataracts."

When viewed in the light of the most knowledgeable estimates of radiation levels required to cause cataracts, two elements are disturbing in these cases. First, ^{there} is the apparent absurdity ⁱⁿ of certain of the claims in the light of accepted facts. Second, ^{there} is evident misinformation and dirth of professional counsel with which reviewing authorities have made certain decisions.

The problem, furthermore, is a growing one. Civilians in ^{Naval} radiation programs have been submitting claims at an increasing rate. As examples, one man who received 11.407 rem over six years has alleged that radiation has caused vacuoles in his eyes. Another individual has alleged that bilateral cataracts have resulted from 29.655 rem received over 18 years. ^{there} ~~It~~ is a dangerous possibility that compensation decisions in favor of undeserving claims will impede the development of nuclear power for both military and civilian uses.

DISCUSSION AND RECOMMENDATIONS

An assessment of the importance of lenticular opacities in the nuclear power program must initially consider the technique whereby

Currently
the opacities are evaluated. ~~Presently~~ initial screening requires a careful ophthalmoscopic examination supported by a general ocular history, physical examination, and measurement of visual acuity and refractive correction. When lenticular opacities are discovered with the ophthalmoscope, or when other findings so warrant, a slit lamp evaluation is performed. The adequacy of this system must be measured by its results and by comparison with possible alternatives.

It cannot be gainsaid that the ophthalmoscope is a relatively crude optical instrument for evaluating lenticular opacities. Indeed, those most skilled in its use are most acutely aware of this fact. Much depends not only upon the skill and dedication of the examiner, but also upon the location and size of the opacity in question. Further, the percentage of individuals in whom opacities are detected is about one order of magnitude lower than results achieved with the slit lamp.

When performed by qualified examiners, however, ophthalmoscopy has been shown to yield consistent results over a large sampling of individuals and over an extended period of time. Moreover, routine detection of small structures like Mittendorf dots, vacuoles, and pigment demonstrates that small lesions can be detected. When combined with a careful history, search for other ocular findings, and visual acuity measurements, it forms the nidus of a satisfactory basic screening. It will not, however, detect early opacities that may be progressive but that do not yet interfere with vision and are either extremely small or remote in location.

Three pilot projects are currently in progress, at shipyards employing civilian personnel, to perform slit lamp examinations on all radiation workers. Two of these centers are further seeking to photograph all opacities as part of baseline data. Their total populations, however, are small enough that the availability of examiners skilled in the slit lamp has not become a problem. Thus far, when dealing with young and middle-aged people, opacities detected with a slit lamp that were invisible to the ophthalmoscope and unassociated with other ocular or systemic findings have, in studies submitted to BUMED, been benign in nature. Whether an increase in pathology will be discovered by making slit lamp examinations routine remains to be determined. Results will of course have to be analyzed in light of the high cost of the program and the overall limited availability of qualified slit lamp personnel.

At the present time it is reasonable to continue using the ophthalmoscope as the basic screening tool for lenticular opacities, with the following modifications: It must be supported by satisfactory history and physical examination. All opacities should be evaluated by slit lamp examination. It is further recommended that the following additional guidelines be used as indication for slit lamp examination:

1. Cases involving recent or abrupt decrease in vision.
2. Presence of amblyopia.
3. History of trauma.
4. Strong family history of cataracts, especially arising at a young age.
5. Unusually high refractive error, especially when 20/20 correction is not achieved.

- ✓ 6. Other ocular pathology.
7. Systemic or metabolic disease known to cause cataracts.
8. Significant use of drugs, topical or systemic, especially steroids, known to cause cataracts.
9. Therapeutic or occupational radiation exposure outside the Navy, especially when the total dose is not known.
10. Evidence of genetic anomalies or prenatal disease.

Finally, since degenerative cataracts appear with increasing frequency in the fifth decade, it is considered advisable to give a slit lamp examination to every radiation worker 45 years of age or older.

The disposition of individuals with lenticular opacities must be determined according to the general principles of the radiation health program. These precepts may be summarized as follows:

1. Insure that entrants into the field will not be placed at unacceptable risk by reason of physical defects.
2. Verify that individuals continue to meet standards, and remove from the program those who develop conditions that might be exacerbated by ionizing radiation.
3. Insure by dosimetry that occupational exposures do not exceed established safe standards.

Every opacity that is detected must be evaluated on the basis of possibly *precluding* enjoining an individual from being a radiation worker. The primary criterion is the etiology of the opacity.

Needless to say, a radiation cataract would disqualify. Because of the inherent safeguards and dose limits in the nuclear power program,

such a lesion would not arise from radiation work except in the event of a nuclear accident. Those cataracts known to arise from acute radiation exposures involved doses of over 100 rads of gamma and over 40 rads of neutron. Lower doses have not caused cataracts. For gamma radiation it is felt that a "practical threshold" may be defined, below which cataractous changes will not occur. Such a threshold has not been defined for neutron doses. It is safe to conclude, then, that in the normal operation of nuclear power plants radiation cataracts will not arise. Examiners might expect to detect such cataracts only among applicants for entry into the program, who may have had either therapeutic or occupational exposures in the past.

Among other types of opacities, punctate markings, vacuoles, and Mittendorf dots occur frequently, are non-progressive, and do not interfere with vision. They may be regarded as physiologic. Traumatic cataracts are usually readily identified with a specific, easily recalled injury. When the accident is remote, the cataract does not progress.

Toxic, metabolic, and senile degenerative cataracts, however, are progressive. Further, they occur in the posterior subcapsular portion of the cortex, and in time may resemble a radiation cataract that has matured. Therefore, it is likely that such cataracts might be mistaken for one caused by radiation. Moreover, it is not known whether radiation will accelerate the growth of these lesions.

Currently

Presently all instances of lenticular opacity are evaluated by

BUMED for enrollment or retention in the nuclear power program. It is

as a prerequisite for the man (2)

The following conditions should not require BUMED review:
 recommended that opacities clearly designated as vacuoles, punctate markings (often multiple), and Mittendorf dots or embryologic remnants

not require BUMED review. Pigment on the lens surface should not be considered a lenticular opacity and likewise should not be reviewed. All other lesions should be evaluated by BUMED. Traumatic cataracts should not be considered disqualifying unless they are too recent to assure that the degree of visual impairment and the extent of cataract formation have stabilized. Toxic, metabolic, and senile degenerative cataracts should be disqualifying, since they do progress and could be associated with radiation exposure, either as the primary cause or a secondary contributing factor. Of the types of disqualifying cataracts, the senile ones are the most frequent. Since they can arise in individuals in their fourth decade, they can on rare occasion be expected to disqualify highly trained individuals at the zenith of their career. Within the past year, in fact, three such individuals were disqualified from the nuclear power program. Since the lesions of at least two had previously been identified, however, an attrition of three per year should not be anticipated. Yet critical though any manpower loss be, *there appears to be* ~~however, no viable alternative appears~~ to resolve this dilemma.

The most disturbing element in the evaluation of lenticular opacities for nuclear power is the medico-legal aspect. Despite reasonable occupational exposure levels and an active radiation health program that has assured compliance with standards, the specter of burgeoning lawsuits serves to make an already cautious employment philosophy even more conservative. Legal considerations often prompt the disqualification of

personnel for defects that increase their risk by either negligible or only theoretical amounts.

Notwithstanding the attention given to radiation health protection and the weight of clinical experience, however, adverse decisions have been handed down. In the cases cited above, the instance of an award granted for a cumulative exposure of 3 rem flouts carefully documented scientific data. In another case, the diagnosis of radiation cataract on morphology alone, discounting the ^{insignificant} ~~insignificance~~ dose of 0.61 ^{rem} ~~R~~ to which the subject was exposed, represents an act of caprice on the part of both the medical examiner and the reviewing board.

Part of the solution to this problem lies in education. It is incumbent first upon medical department personnel participating in the radiation health program to be fully acquainted with all aspects of lenticular opacities as they relate to evaluating individuals for nuclear power. It is also important for the line to be aware of pertinent medical criteria. It is also necessary to understand that the intensity of the radiation health program results, not from the risk incurred by the doses people receive, but by the commitment to minimize risk in any possibly way and to document the insignificance of the risk. These steps are preliminary to educating both radiation workers and the general public regarding radiation hazards.

Because of the highly technical nature of nuclear power, as regards both its physics and its biomedical ramifications, and because judicial authorities are generally untrained in these matters, it would further

seem advisable to create a board or agency of recognized experts in matters regarding radiation health. This board would then be available to review claims ^{and make recommendations to all judicial agencies,} whether federal or state, ^{and} concerning either military or civilian personnel. This would insure that an acceptable level of expertise ^{at all times} would be available for consultation, and ^{would} provide a necessary consistency in the establishment of important and far-reaching precedent.

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Table I: Enlisted Nuclear Power School Students, May, 1973 to May, 1974

	<u>No. of Candidates</u>	<u>No. with Lenticular Opacities</u>	<u>Percent</u>
Bainbridge	2,204	263	11.93%
Mare Island	<u>1,835</u>	<u>199</u>	<u>10.84%</u>
TOTAL	4,039	462	11.44%

Table II: Enlisted Nuclear Power School Students, May - December, 1973

	<u>No. of Candidates</u>	<u>No. with Lenticular Opacities</u>	<u>Percent</u>
Bainbridge	1,251	190	15.19%
Mare Island	<u>840</u>	<u>98</u>	<u>11.67%</u>
TOTAL	2,091	288	13.77%

Table III: Enlisted Nuclear Power School Students, January - May, 1974

	<u>No. of Candidates</u>	<u>No. with Lenticular Opacities</u>	<u>Percent</u>
Bainbridge	953	73	7.66%
Mare Island	<u>995</u>	<u>101</u>	<u>10.15%</u>
TOTAL	1,948	174	8.93%